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(54) **EV BATTERY PACK WITH BATTERY COOLING ASSEMBLY AND METHOD**

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(58) **Field of Classification Search**

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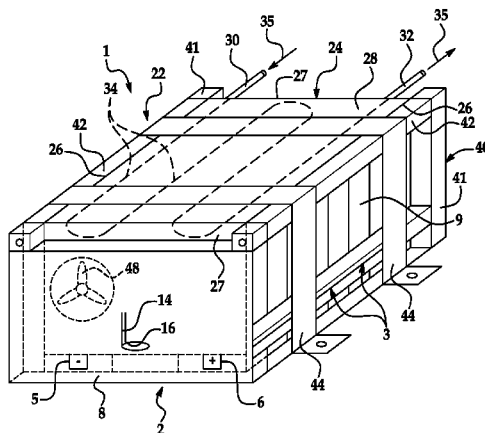
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(57) **ABSTRACT**

An electric vehicle battery pack includes an array of battery cells each cell having an upper cell surface and a lower cell surface, the lower cell surface having a positive and a negative terminal; and a thermal assembly in thermally-conductive contact with the upper cell surfaces of the array. A battery pack cooling method is also disclosed.

20 Claims, 3 Drawing Sheets



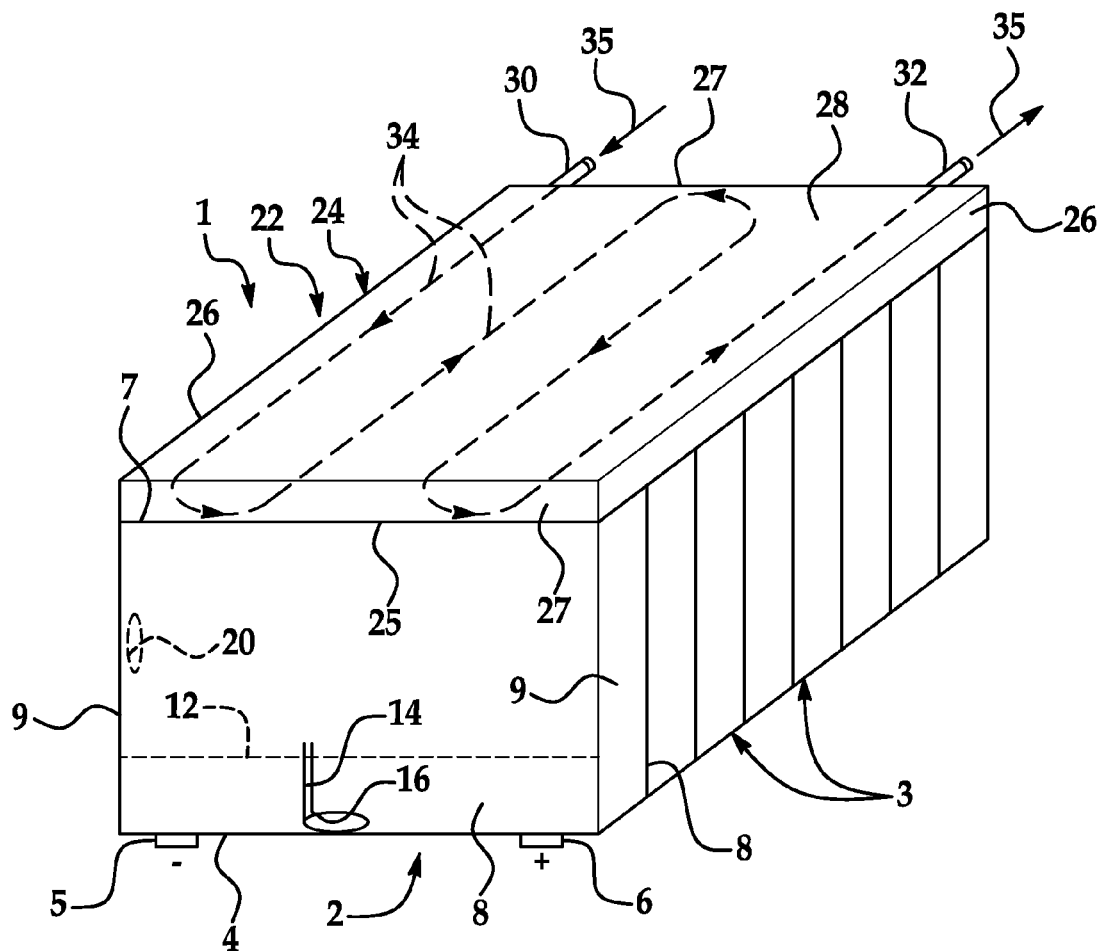


FIG. 1

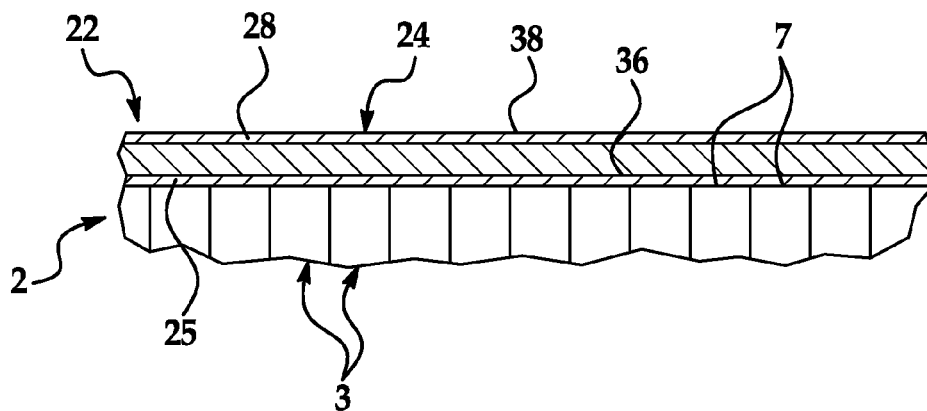
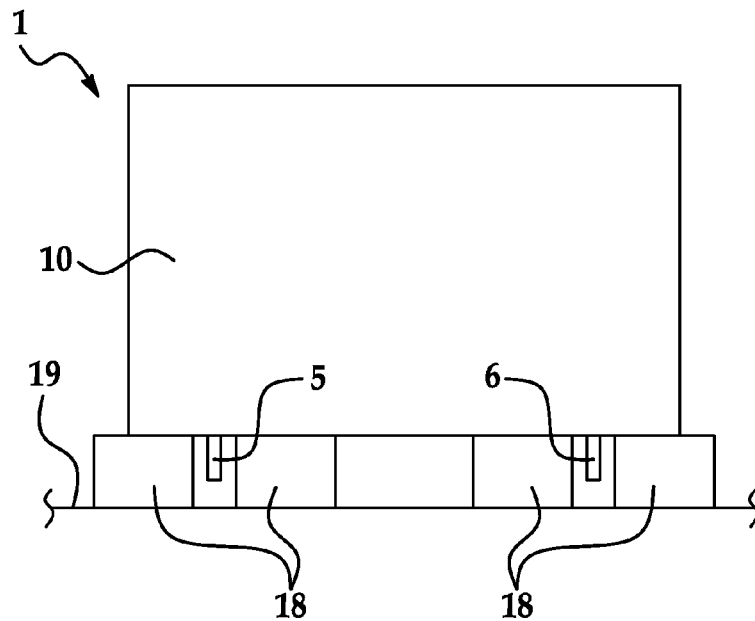
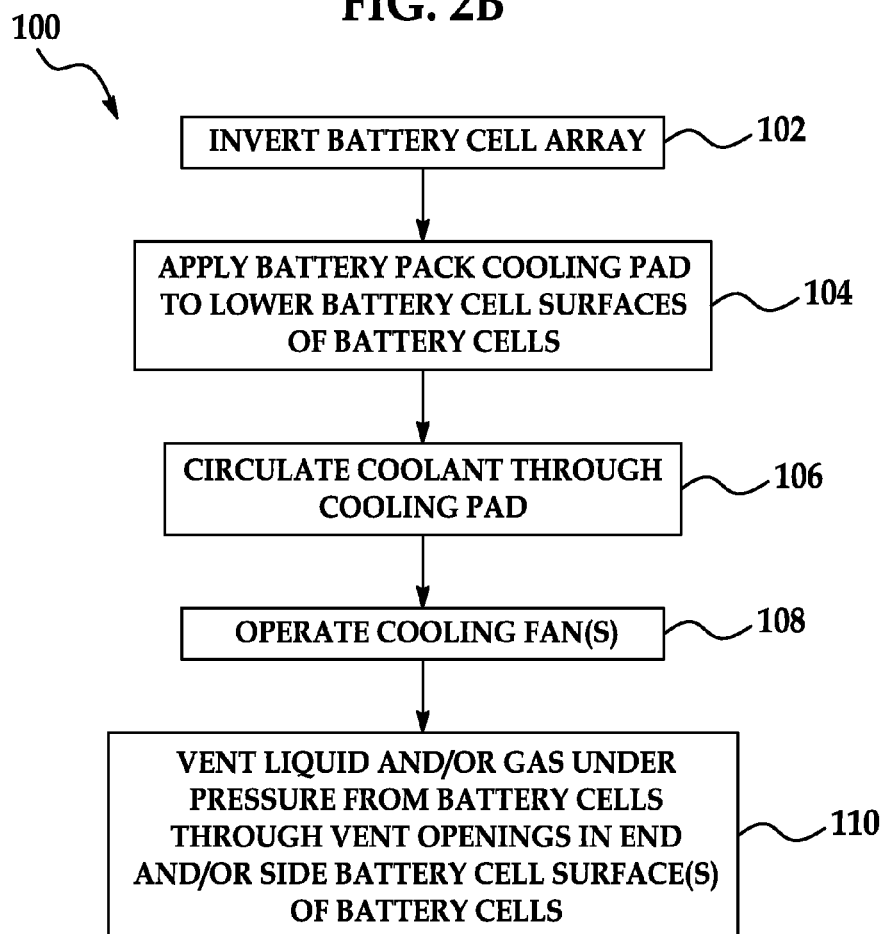


FIG. 1A

FIG. 2A

**FIG. 2B****FIG. 3**

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EV BATTERY PACK WITH BATTERY COOLING ASSEMBLY AND METHOD

FIELD

Illustrative embodiments of the disclosure are generally directed to battery packs for electric vehicles (EVs), and other directly or indirectly used battery packs. More particularly, illustrative embodiments of the disclosure are directed to an EV battery pack with battery cooling assembly and a method which facilitate uniform and efficient cooling of EV batteries.

BACKGROUND

Due to the requirements of a high efficiency, low-cost system to transfer heat which is generated by battery cells with minimum power and volume, EV battery packs may utilize a liquid-cooled pad.

Accordingly, an EV battery pack with battery cooling assembly and method which facilitates uniform and efficient cooling of EV batteries may be desirable.

SUMMARY

Illustrative embodiments of the disclosure are generally directed to an electric vehicle battery pack with battery cooling assembly. An illustrative embodiment of the electric vehicle battery pack includes an array of battery cells each cell having an upper cell surface and a lower cell surface, the lower cell surface having a positive and a negative terminal; and a thermal assembly in thermally-conductive contact with the upper cell surfaces of the array.

Illustrative embodiments of the disclosure are further generally directed to a battery pack cooling method. An illustrative embodiment of the battery pack cooling method includes inverting an array of battery cells of an electric vehicle battery pack having an upper cell surface and a lower cell surface, the lower cell surface having a positive and a negative terminal; applying a thermal assembly to the upper cell surfaces of the array; and circulating coolant through the thermal assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

Illustrative embodiments of the disclosure will now be described, by way of example, with reference to the accompanying drawings, in which:

FIG. 1 is a perspective view of a portion of an illustrative embodiment of an EV battery pack fitted with a battery cooling assembly;

FIG. 1A is a cross-sectional view of the junction between a battery cell array and a battery pack cooling pad according to an illustrative embodiment of the EV battery pack with battery cooling assembly;

FIG. 2 is a perspective view of an illustrative embodiment of a portion of an EV battery pack fitted with a battery cooling assembly having a battery pack frame;

FIG. 2A is a side view of an EV battery pack fitted with a battery cooling assembly;

FIG. 2B is an end view of an EV battery pack with a battery cooling assembly, the battery pack supported on a support surface by battery cell supports; and

FIG. 3 is a flow diagram of an illustrative embodiment of a battery pack cooling method.

DETAILED DESCRIPTION

The following detailed description is merely exemplary in nature and is not intended to limit the described embodi-

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ments or the application and uses of the described embodiments. As used herein, the word “exemplary” or “illustrative” means “serving as an example, instance, or illustration.” Any implementation described herein as “exemplary” or “illustrative” is not necessarily to be construed as preferred or advantageous over other implementations. All of the implementations described below are exemplary implementations provided to enable users skilled in the art to practice the disclosure and are not intended to limit the scope of the claims. Moreover, the illustrative embodiments described herein are not exhaustive and embodiments or implementations other than those which are described herein and which fall within the scope of the appended claims are possible. Furthermore, there is no intention to be bound by any expressed or implied theory presented in the preceding technical field, background, brief summary or the following detailed description.

Referring initially to FIGS. 1, 1A, 2 and 2A, an illustrative embodiment of a thermal assembly such as a battery cooling assembly **22** placed in thermal contact with an EV (Electric Vehicle) battery cell array **2** in an EV battery pack **1** is shown. The EV battery pack **1** may be suitable for implementation in an electric vehicle such as an HEV (Hybrid Electric Vehicle), for example and without limitation. The EV battery pack **1** may include a battery pack housing **10** having a housing cover **10a** and in which is contained at least one battery cell array **2** having multiple, adjacent battery cells **3**. As shown in FIG. 2A, a bus bar **11** may be disposed in electrical contact with the battery cells **3** in each battery cell array **2**. Each battery cell **3** may include an upper battery cell surface **4** having a negative terminal **5** and a positive terminal **6**. Each battery cell **3** may further include a lower battery cell surface **7** which is opposite the upper battery cell surface **4**, a pair of spaced-apart end battery cell surfaces **8** and a pair of spaced-apart side battery cell surfaces **9** extending between the end battery cell surfaces **8**. Each battery cell **3** may contain an electrolyte solution **12**. A vent conduit **14** may communicate with the electrolyte solution **12**. At least one end vent opening **16** which communicates with the vent conduit **14** may be provided in one of the end battery surfaces **8**. Additionally or alternatively, at least one side vent opening **20** may be provided in one of the side battery surfaces **9** of each battery cell **3**.

The battery cooling assembly **22** may include a battery pack cooling pad **24**. In some embodiments, the battery cooling pad **24** may be generally elongated and rectangular with a battery contact surface **25**, a pad outer surface **28** and a pair of side pad surfaces **26** and a pair of end pad surfaces **27** extending between the battery contact surface **25** and the pad outer surface **28**. The battery cooling pad **24** may include any thermally-conductive metal, plastic and/or other material to increase heat transfer between battery cells and cooling pad.

As further shown in FIG. 1, a coolant inlet **30** and a coolant outlet **32** may extend from the battery pack cooling pad **24**. A coolant path **34** may extend through the battery pack cooling pad **24** in fluid communication with the coolant inlet **30** and the coolant outlet **32**. In some embodiments, the coolant inlet **30** and the coolant outlet **32** may extend from the end pad surface **27** in spaced-apart relationship to the coolant inlet **30**, as shown. The coolant path **34** may extend in a winding, serpentine path from the coolant inlet **30** to the coolant outlet **32**. The winding cooling path is one example, any other cooling path pattern can be used also, for example, several parallel line coolant paths from one end of cooling pad to another end.

As shown in FIG. 2, in some embodiments, at least one cooling fan 48 may be installed around the battery cell array 2 to impart uniform battery cell temperature. The cooling fan 48 could be powered by either solar or battery. As shown in FIG. 2A, in some embodiments, at least one cooling fan 48 may be provided inside the battery pack housing 10 above the battery cell array 2. The location of the cooling fan or fans 48 may be optimized for the best air circulation, lowest noise and minimum power consumption according to the knowledge of those skilled in the art. To maximize the air circulation, the spacer can be installed between neighboring cells.

With the battery cell array 2 in an inverted position and the upper battery cell surface 4 facing downwardly and the lower battery cell surface 7 facing upwardly, the battery pack cooling pad 24 may be placed in thermally-conductive contact with the lower battery cell surfaces 7 of the respective battery cells 3. The lower battery cell surfaces 7 and the battery contact surface 25 of the battery pack cooling pad 24 may be rendered sufficiently smooth that the battery pack cooling pad 24 can "stick" to the battery cells 3 seamlessly. As shown in FIG. 1A, in some embodiments, a thermally conductive layer 36, such thermal compound may be sandwiched between the battery contact surface 25 of the battery pack cooling pad 24 and the lower battery cell surfaces 7 of the respective battery cells 3. Thermal compound fills the space between the bottom of cell and cooling pad, and improve the thermal transfer from battery cell to cooling pad. A thermally insulating layer 38 may be placed on the pad outer surface 28 of the battery pack cooling pad 24, to further protect battery from performance degradation due to thermal soak. Generally speaking, it is recommended to reduce battery power to avoid some safety issues when cell temperature is high. Pressure may be applied against the battery pack cooling pad 24 to press the battery pack cooling pad 24 and the battery cell array 2 together to ensure that the lower battery surfaces 7 of the battery cells 3 are tightly connected with the battery contact surface 25 of the battery pack cooling pad 24. As shown in FIG. 2B, in some embodiments, the EV battery pack 1 may be supported by multiple battery cell supports 18 which support the negative terminals 5 and the positive terminals 6 of the battery cells 3 in the battery cell array 2 over a support surface 19.

In exemplary application, the battery cell array 2 is inverted such that the upper battery cell surfaces 4 of the respective battery cells 3 face downwardly and the lower battery cell surfaces 7 face upwardly. The battery cooling pad 24 is applied to the lower battery surfaces 7 of the battery cells 3, as was heretofore described with respect to FIG. 1. As shown in FIG. 2, the inverted battery cell array 2 and battery cooling pad 24 may be secured in a battery pack frame 40 which protects the battery cell array 2 and battery pack cooling pad 24 from damage due to vibration when the electric vehicle in which the EV battery pack 1 is installed traverses rough surfaces. The battery array frame 40 may support the inverted battery cells 3 and the battery pack cooling pad 24 above the battery cells 3 and may compress the cells to increase the life of the cells.

The battery array frame 40 may have any design or construction which is suitable for the purpose. In some embodiments, the battery array frame 40 may be thermally conductive metal and/or other material and may include multiple corner frame members 41 which are placed at the respective corners of the battery cell array 2. Side frame members 42 may extend between the corner frame members 41 along the respective longitudinal edges of the battery cell array 2. The side frame members 42 may be fitted with frame

mount brackets 44 which facilitate bolted and/or other attachment of the EV battery pack to the electric vehicle and to ensure the cells are compressed inside vehicle to extend the life of battery cells.

Throughout operation of the EV battery pack 1, heat may be generated inside the battery cells 3 of the battery cell array 2. Liquid coolant 35 may be circulated through the coolant inlet 30, coolant path 34 and coolant outlet 32, respectively. Thus, heat is dissipated from the interiors of the battery cells 3 to the circulating coolant 35. The battery cell is filled full or partially with electrolyte solution 12 (FIG. 1). The cell is cooled by convection through liquid and/or gas from the coolant path 34 at the lower battery cell surfaces to the upper battery cell surfaces 4 of the respective inverted battery cells 3. The cooled electrolyte solution 12 dissipates heat from the upper battery cell surfaces 4 of the battery cells 3. Additional cooling may occur by conduction from the coolant path 34, through the battery pack frame 40 to the upper battery cell surfaces 4, imparting uniformity to the temperature of the battery cells 3. The cooling fan or fans 48 may be operated to further impart uniformity to the temperature distribution within the battery cells 3.

With the more uniform temperature field within each battery cell 3 and increased heat transfer to the lower battery cell surfaces 7, the temperature of the lower battery cell surfaces 7 may be raised. This may substantially improve the cooling pad heat transfer condition due to larger delta temperature between the coolant and the cell to facilitate a lower coolant fluid rate and a higher coolant fluid temperature. The lower requirement on cooling fluid rate and temperature may be met by lowering the cooling fan speed and/or lowering or eliminating extra AC cooling to reduce cooling system cost and increase vehicle fuel economy and available power from the EV battery pack 1. In the event that pressure accumulates in the battery cells 3 and exceeds a predetermined threshold, any gas and/or electrolyte solution 12 may be vented from the battery cells 3 through the end vent opening or openings 16 and/or the side vent opening or openings 20. If due to the upside down installation of the cell, the vent and CID are located at bottom and manufacture prefers to vent gas out of the cell first, special design is needed. For example, a tube 14 may be constructed inside the cell to reach above the electrolyte level to vent out the gas first.

Referring next to FIG. 3, an illustrative embodiment of a battery array cooling method 100 is shown. At block 102, a battery cell array of an EV battery array is inverted with the normally lower battery cell surfaces facing upwardly and the normally upper battery cell surfaces and the negative and positive terminals of each battery cell facing downwardly. At block 104, a battery array cooling pad is applied to the lower battery cell surfaces of the battery cells. At block 106, coolant is circulated through the battery pack cooling pad. At block 108, a cooling fan or fans may be operated to optimize heat transfer and uniformity of cooling. At block 110, liquid and/or gas pressure (fluid pressure) may be vented from the battery cells through vent openings in the end surfaces and/or the side surfaces of the battery cells.

Although the embodiments of this disclosure have been described with respect to certain exemplary embodiments, it is to be understood that the specific embodiments are for purposes of illustration and not limitation, as other variations will occur to those of skilled in the art.

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What is claimed is:

1. An electric vehicle battery pack, comprising:
an array of battery cells each cell having an upper cell
surface and a lower cell surface, the lower cell surface
having a positive and a negative terminal; and
a thermal assembly in thermally-conductive contact with
the upper cell surfaces of the array, the array of battery
cells and the thermal assembly secured within a battery
array frame, said array of battery cells inverted such
that lower cell surfaces within said battery array frame
are configured to be adjacently disposed to the electric
vehicle upon mounting of the battery array frame on the
electric vehicle.
2. The electric vehicle battery pack of claim 1 further
comprising at least one vent opening in each of the array of
battery cells, the at least one vent opening capable of venting
gas or liquid.
3. The electric vehicle battery pack of claim 2 wherein the
at least one vent opening is in an end battery cell surface of
each of the array of battery cells.
4. The electric vehicle battery pack of claim 2 wherein the
at least one vent opening is in a side battery cell surface of
each of the array of battery cells.
5. The electric vehicle battery pack of claim 1 further
comprising at least one cooling fan in the array of battery
cells.
6. The electric vehicle battery pack of claim 1 wherein the
thermal assembly comprises a coolant inlet, a coolant outlet
and a coolant path disposed in fluid communication with the
coolant inlet and the coolant outlet and in thermally con-
ductive contact with the upper cell surfaces of the array.
7. The electric vehicle battery pack of claim 6 wherein the
coolant path is disposed in a winding serpentine configura-
tion.
8. The electric vehicle battery pack of claim 1 further
comprising a thermally conductive layer sandwiched
between the array of battery cells and the thermal assembly.
9. The electric vehicle battery pack of claim 1 wherein the
battery array frame comprises corner frame members dis-
posed at respective corners of the array of battery cells and
side frame members extending between the corner frame
members along respective longitudinal edges of the array of
battery cells.
10. The electric vehicle battery pack of claim 1 wherein
the positive and a negative terminal are supported by respec-
tive support members, the support members configured to be
supported on a support surface.

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11. An electric vehicle battery array, comprising:
an array of battery cells each cell having an upper cell
surface and a lower cell surface, the lower cell surface
having a positive and a negative terminal; and
a thermal assembly in thermally-conductive contact with
the upper cell surfaces of the array; and
a battery array frame securing the thermal assembly on
the array of battery cells, the array of battery cells and
the thermal assembly secured within the battery array
frame, said array of battery cells inverted such that
lower cell surfaces within said battery array frame are
configured to be adjacently disposed to the electric
vehicle upon mounting of the battery array frame on the
electric vehicle.
12. The electric vehicle battery pack of claim 11 further
comprising at least one vent opening in each of the array of
battery cells, the at least one vent opening capable of venting
gas or liquid.
13. The electric vehicle battery pack of claim 12 wherein
the at least one vent opening is in an end battery cell surface
of each of the array of battery cells.
14. The electric vehicle battery pack of claim 12 wherein
the at least one vent opening is in a side battery cell surface
of each of the array of battery cells.
15. The electric vehicle battery pack of claim 11 further
comprising at least one cooling fan in the array of battery
cells.
16. The electric vehicle battery pack of claim 11 wherein
the thermal assembly comprises a coolant inlet, a coolant
outlet and a coolant path disposed in fluid communication
with the coolant inlet and the coolant outlet and in thermally
conductive contact with the upper cell surfaces of the array.
17. The electric vehicle battery pack of claim 16 wherein
the coolant path is disposed in a winding serpentine con-
figuration.
18. The electric vehicle battery pack of claim 16 wherein
the battery array frame comprises corner frame members
disposed at respective corners of the array of battery cells
and side frame members extending between the corner
frame members along respective longitudinal edges of the
array of battery cells.
19. The electric vehicle battery pack of claim 11 further
comprising a thermally conductive layer sandwiched
between the array of battery cells and the thermal assembly.
20. The electric vehicle battery pack of claim 11 wherein
the battery pack frame comprises a plurality of corner frame
members disposed at respective corners of the battery cell
array and a plurality of side frame members connecting the
plurality of corner frame members.

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